

SCIENCE AND TECHNOLOGY IN THE NATIONAL INTEREST



FY2011 Highlights

LAWRENCE LIVERMORE
NATIONAL LABORATORY



Wind power photo courtesy of Vattenfall.



ABOUT THE COVER

With a broad national security mission, Lawrence Livermore National Laboratory (LLNL) seeks solutions to the 21st century's most pressing problems. The target chamber in the National Ignition Facility, where scientists are pursuing the quest for fusion ignition, and the test launch of a Minuteman III provide the background for a researcher synthesizing molecules in the search for an effective carbon capture catalyst. High-performance computing at the Laboratory supports applications from stewardship of the nation's nuclear deterrent to modeling the wakes that form behind wind turbines.

ABOUT THE LABORATORY

Lawrence Livermore National Laboratory was founded in 1952 to enhance the security of the United States by advancing nuclear weapons science and technology. With our world-class research capabilities, a talented and dedicated workforce, and a tradition of innovation and intellectual integrity, the Laboratory anticipates, develops, and delivers solutions to problems of national and global importance. The Laboratory is managed by Lawrence Livermore National Security, LLC (LLNS), for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE).



THE YEAR IN REVIEW



Fiscal Year 2011

- 2 Director's Message
- 3 FY2011 Highlights
- 4 Nuclear Deterrence
- 6 National Ignition Facility
- 8 Global Security
- 10 Energy and Environment
- 12 Science and Technology
- 16 Safety, Security, and Sustainability
- 18 Management and Operations
- 20 Community Connections
- 22 Workforce Recognition
- 24 Board of Governors



Director's Message

Continuing a long-standing tradition of science in the national interest

For nearly six decades, Lawrence Livermore National Laboratory (LLNL) has pursued breakthroughs in science and technology and applied these advances to meet important national needs. For 40 of those years, I've been privileged to have had the honor of working with outstanding fellow employees and incredibly dedicated project teams. This Laboratory has made it a point to direct its technical prowess at problems most others consider to be "too hard," and that focus has been the source of many remarkable achievements. I'm pleased to say that the tradition continues.

As described in this annual report for fiscal year (FY) 2011, we are using some of the world's most advanced computer simulations and experimental facilities to sustain confidence in the nation's strategic deterrent. For example, researchers conducted an important series of stockpile stewardship experiments at the National Ignition Facility (NIF) and resolved a key issue about weapons performance. Laboratory scientists and engineers also devised innovative technologies to help stem nuclear proliferation and counter terrorism, enhance biosecurity and human health,

protect against cyber threats, and develop energy alternatives to fossil fuels.

Following the Fukushima nuclear reactor disaster, we worked around the clock for weeks to provide plume predictions of the released radioactivity to decision makers and emergency responders in both the United States and Japan. In addition, we completed preparations for the 2012 delivery of the groundbreaking Sequoia supercomputer, made significant progress toward achieving fusion ignition at NIF, began the effort to extend the stockpile life of the

W78 intercontinental ballistic missile (ICBM) warhead, and opened our High-Performance Computing Innovation Center at the Livermore Valley Open Campus.

The accomplishments highlighted in this report (and many more) position Livermore well for continuing success in the years ahead. As LLNL prepares to observe its 60th anniversary, I am confident that this Laboratory, now under the able leadership of Dr. Penrose (Parney) C. Albright, will continue to tackle and solve the most significant technical challenges facing our nation.

Stepping down as director of this extraordinary institution was a difficult decision for me, but it was time for me to move on. I thank all of LLNL's sponsors and stakeholders for your continuing strong support for the Laboratory. I thank my colleagues and friends at Livermore for your passion and creativity, your dedication and perseverance, your commitment and integrity, and your unwavering service to the nation.

George H. Miller

LLNL Director

LLNS President

FY2011 Highlights



(Left to right) Target and target assembly prior to a shot at the National Ignition Facility (NIF). Russian laboratory directors tour NIF. Forensic Science Center researchers analyze samples from the Fukushima nuclear reactor disaster.

Director Retires, Successor Named

In April, George Miller announced his plan to retire as LLNL director and president of LLNS before the end of the year, closing a career that spanned four decades. In response to Miller's announcement, NNSA Administrator Thomas D'Agostino declared that, "Over the course of his long and distinguished career at Lawrence Livermore National Laboratory, George has been a critical player in our nation's nuclear security... During his tenure at Livermore, the Lab has accomplished amazing things. Our nation is safer and more secure, and global security has been enhanced by the outstanding work done under George's leadership." Following a national search led by the University of California, Parney Albright was selected as the next Laboratory director, effective December 1, 2011.

W78 Life-Extension Program

LLNL and the U.S. Air Force launched a concept development study to extend the life of the Minuteman III's W78 warhead. The life-extension program—a decade-long effort to evaluate options for addressing concerns identified in surveillance of W78 units and then implement the necessary changes—will enable the system to remain in the stockpile for an additional 30 years.

Groundbreaking Experiments at NIF

Experiments at the National Ignition Facility made substantial progress in the quest for ignition, completing the first shots using

deuterium–tritium fuel and setting a new record high yield of 5.7×10^{14} neutrons. Experiments also led to the resolution of a key weapon performance issue. A total of 286 shots were fired, including 62 for the ignition campaign and 50 for high-energy-density science applications. Through the iterative process of pre-shot prediction, experiment, post-shot data analysis, and design of the next experiment, LLNL researchers broke new ground in physics understanding and optimization for ignition.

Meeting with Russian Lab Directors

LLNL hosted a meeting of the U.S. and Russian national security research laboratory directors. The meeting, the first since 2004, provided an opportunity for the directors and representatives of Rosatom and NNSA to develop a set of next steps toward collaboration in nonproliferation, basic and applied science, energy and the environment, and nuclear medicine. Follow-on activities have included an inertial confinement fusion technical workshop at LLNL and a plutonium materials conference in Snezhinsk, Russia.

Support to Fukushima Response

Laboratory scientists at the National Atmospheric Release Advisory Center (NARAC) provided critical support to agencies in the United States and Japan responding to the Fukushima nuclear reactor disaster. NARAC was activated on March 11, 2011, and generated a steady stream of up-to-date atmospheric dispersion predictions, plume projections, and

radiation dose estimates. During the height of the crisis, NARAC operated around the clock for 22 days. By the time active operations ended in mid-May, NARAC had logged more than 5,000 person-hours and produced more than 300 projections and analyses.

HPC Innovation Center

The High-Performance Computing Innovation Center opened in June, the first new facility to be built at the Livermore Valley Open Campus. The center provides a collaborative setting for LLNL scientists and partners in industry and academia to advance high-performance computing and apply it to create solutions for smart energy, product development and manufacturing, information management, communications, and other 21st-century challenges.

National Media Coverage

FY2011 was a banner year for national media coverage. Stories about the Laboratory's work on military helmet safety, elements 114 and 116, combating antibiotic-resistant bacteria, protecting against an improvised nuclear device, the High Explosives Applications Facility, and NARAC were carried variously by *The New York Times*, *USA Today*, *Los Angeles Times*, *The Wall Street Journal*, *Scientific American*, Associated Press, National Public Radio, Fox News, BBC News, and CNN. In addition, the White House blog prominently featured LLNL's exhibit at the USA Science and Engineering Festival.

Nuclear Deterrence

Ensuring the safety, security, and effectiveness of the enduring stockpile

LLNL's foremost responsibility as a national security laboratory is to ensure the safety, security, and effectiveness of the nation's nuclear arsenal. Through experiments, theory, and simulations, scientists and engineers elucidate the underlying science of nuclear weapons and the effects of aging on weapons materials and performance. The knowledge gained enhances their ability to assess the condition of stockpile weapons, develop modifications as needed, and certify with confidence the condition of the stockpile in the absence of nuclear testing.

Annual Stockpile Assessment

The Laboratory completed Cycle 16 of the Annual Stockpile Assessment. This year's assessment benefited from reduced uncertainties and increased scientific rigor attributable to improved simulation models, results from recent plutonium aging experiments, and better fundamental nuclear data derived from joint work with Los Alamos National Laboratory (LANL). An Independent Nuclear Weapon Assessment Process (INWAP) was implemented for the first time in 2011 to strengthen peer review. Through data exchanges, the nuclear design laboratories conduct comprehensive analyses of each other's designed weapons in support of annual assessments, closure of significant findings, and certification of weapon modifications made in life-extension programs (LEPs). Livermore INWAP teams are studying the LANL-developed B61 bomb and W78 warhead. For the W78 effort, for example, the LLNL team developed supportive physics and materials models, prioritized potential risks to guide engineering studies, and briefed its findings to LANL scientists and managers.

W78 Life-Extension Program

In June, LLNL and the U.S. Air Force launched a concept development (Phase 6.1) study to extend the life of the W78 Minuteman III warhead. The W78, which is the dominant system for the ICBM leg of the nation's nuclear deterrent, has aged beyond its planned service life, and it will take a decade-long effort to study options to address concerns identified through surveillance of W78 units and then to implement the necessary changes. This study will evaluate different life-

extension approaches—including refurbishment, reuse, or replacement of weapon components—and assess the impacts of incorporating additional safety and security features. Hydrodynamic experiments (discussed below) are maturing technologies for use in ongoing and future LEPs. The W78 LEP will enable the system to remain in the stockpile for an additional 30 years. It will also serve to develop the knowledge, skills, and experience of the next generation of stockpile stewards at LLNL.

New Supercomputers

In FY2011, LLNL completed a major cooling and power upgrade project and procured a massive (50-petabyte) parallel file system in preparation for the arrival of the 20-petaflop/s (20 quadrillion floating-point operations per second) Sequoia machine, to be delivered in phases in 2012. Developed by IBM, Sequoia incorporates new BlueGene/Q technology and will be the world leader in both peak speed and power efficiency. Also this year, LLNL led the vendor selection team for NNSA's Tri-Lab Linux Capacity Cluster 2. Arriving in FY2012, the computers will provide Lawrence Livermore, Los Alamos, and Sandia national laboratories with 3 petaflop/s of computing power to run simulations that do not require the largest supercomputers. By procuring standardized hardware and software environments for the

The U.S. Air Force and LLNL began studying options to extend the life of the W78 warhead, which is currently deployed on the Minuteman III Intercontinental Ballistic Missile (ICBM). Flight tests gather valuable systems performance data as part of stockpile surveillance.



IBM officially unveiled the BlueGene/Q system (Sequoia) at the SC11 supercomputing conference in November 2011. Sequoia continues the Laboratory's long-standing partnership with IBM to achieve breakthroughs in computing capability.

Linux clusters, the laboratories will realize significantly reduced costs, increased efficiencies, and enhanced collaboration.

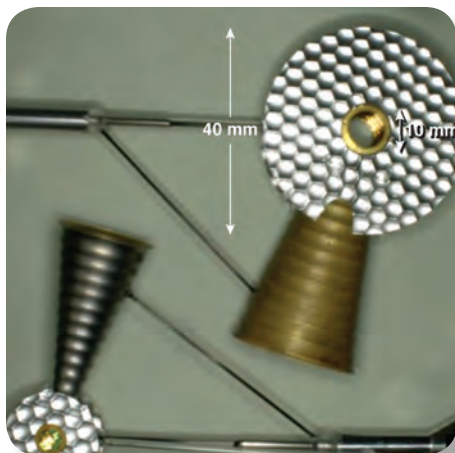
Improved Predictive Capabilities

High-energy-density physics experiments at the National Ignition Facility in 2011 provided key data to complete a top-level stockpile stewardship milestone. The results greatly enhance the predictive capabilities of simulation models of nuclear weapons performance. These models underpin stockpile surveillance,

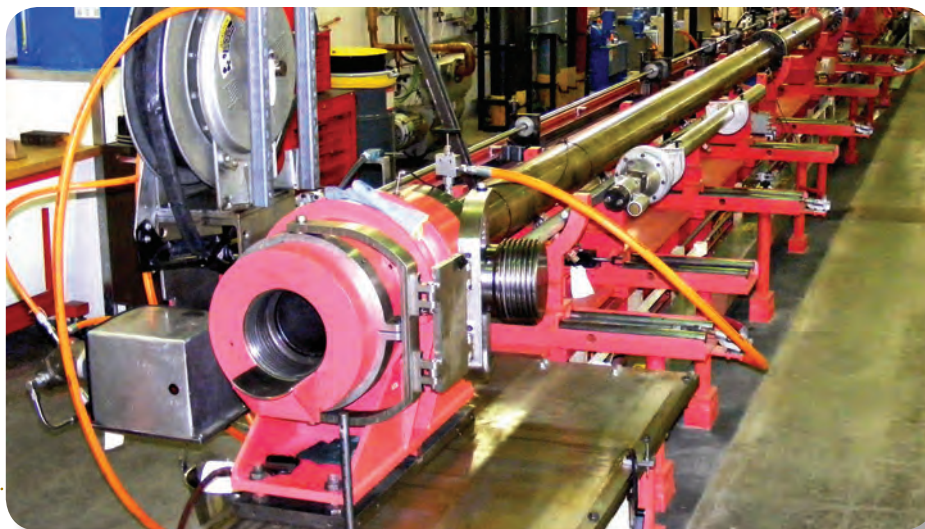
assessments of the condition of weapons, and the ability to deal with issues as they arise and certify changes made to warheads. In support of NNSA's Predictive Capability Framework, Laboratory researchers also made notable advances in studies of boost physics, plutonium aging, and material properties under extreme conditions. New equation-of-state data with reduced uncertainties are being used in weapons simulations. In addition, new aging models were implemented for materials in critical weapons subassemblies.

Stockpile Stewardship Experiments

Complementing experiments at NIF, LLNL also successfully fielded two integrated weapons experiments in 2011. One experiment at the Contained Firing Facility at Site 300 tested advanced safety and security concepts for future LEPs; another at LANL's Dual-Axis Radiographic Hydrodynamics Test facility demonstrated more advanced capabilities for certifying warheads. Both tests returned excellent data to compare with detailed pre-shot predictions of performance. After completing significant upgrades to meet more demanding operational requirements, Livermore also conducted the first in a series of shock plutonium physics experiments at the Joint Actinide Shock Physics Experimental Research (JASPER) facility at the Nevada National Security Site. Research on the properties of materials (including plutonium) at extremely high pressures will also benefit from continuing development of explosively driven pulsed-power devices in the Phoenix Program; five successful Phoenix tests were conducted in 2011.



The size of an ignition hohlraum, a target used in a NIF equation-of-state experiment (left) is shown next to a larger material strength experimental target (right). The mounted cones enable collection of precise shock wave timing data.



A two-stage gas gun, similar to the Joint Actinide Shock Physics Experimental Research (JASPER) system, was relocated to LLNL's High Explosives Applications Facility (HEAF) in 2011. Shock physics tests at HEAF prove out experimental techniques to be used at JASPER, advance the science of large planets, and support a variety of national security applications.

National Ignition Facility

Progressing toward fusion ignition and turning NIF into a user facility for stockpile stewardship and high-energy-density science

The campaign to achieve fusion ignition and burn is well under way at the National Ignition Facility, the world's most energetic laser system. During FY2011, a total of 286 shots were fired on NIF, with 62 shots for ignition and 50 shots for high-energy-density science applications, including a series that helped to resolve a major issue about nuclear weapons performance. In addition to being a cornerstone of stockpile stewardship, NIF experiments provide valuable insights into the nature of the universe and advance the prospect of laser fusion as a carbon-free energy source.



Progress toward Ignition

LLNL and its partners in the National Ignition Campaign (NIC) made substantial progress in the quest to demonstrate fusion ignition. Experiments at NIF set records for important integrated measures of performance, including a new high in neutron yield (5.7×10^{14}). Researchers achieved a top-level milestone in June 2011 with the first integrated ignition experiments. The campaign demonstrated sustained operations at laser energies of 1.3 MJ (megajoules) with the full set of ignition diagnostics, hohlraum performance, and the capability to optimize capsule performance. The campaign culminated in the implosion of a layered target using a fuel mixture of tritium, hydrogen, and deuterium (THD) at cryogenic temperatures. The experiment achieved a factor of 20 to 30 times better performance than the

The operations crew gathered in the NIF Control Room on June 9, 2011, before commencing the first shot with a cryogenically cooled layered target using deuterium–tritium (DT) fuel. Seven such DT experiments were carried out in 2011, setting records in neutron yield (5.7×10^{14}) and areal density (1.1 gm/cm^2).

first THD implosion in September 2010. NIC also conducted the first experiments using an equimolar (50:50) deuterium–tritium (DT) fuel mixture in the target.

Design changes were made to the hohlraum and target capsule materials for a subsequent series of experiments, which further improved performance by a factor of two. One DT-fueled

shot was conducted at a record-setting 1.6 MJ of ultraviolet laser energy. For the year, the overall measure of implosion quality was improved by more than a factor of 50, bringing it to within about a factor of 10 of what is required for ignition.

NIC researchers are optimizing the target implosion by adjusting three target parameters and 14 parameters related to laser pulse shape and timing. They have qualified and are using in ignition experiments seven different types of surrogate physics target platforms to optimize implosion symmetry and the timing and amplitude of the four shocks that implode the fusion fuel. Through the iterative process of pre-shot prediction, experiment, post-shot data analysis, and design of the next experiment, LLNL is breaking new ground in physics



New diagnostics installed at NIF include a neutron time-of-flight detector. Data gathered by the instrument enable scientists to calculate areal density, an important measure of whether there is sufficient imploded fuel mass to sustain a fusion reaction.

understanding on the path to ignition. Progress to date has been reviewed and commended by the NIC Ignition Review, chaired by DOE Under Secretary Steven Koonin, and other technical review committees. Ignition in FY2012 remains the goal for NIC.

High-Energy-Density Science

The Laboratory conducted a highly successful month-long campaign of high-energy-density science experiments at NIF for user groups from LLNL's weapons program, LANL, University of California at Berkeley, and Princeton University. Altogether, 34 target shots were conducted to study the properties of materials at extreme conditions and to understand how x rays propagate in plasmas. One series of experiments supported the completion of a top-level stockpile stewardship milestone (see page 5). Other experiments focused on developing and applying a new technique for gathering equation-of-state data to characterize the properties of highly compressed but unheated materials—in this case, tantalum and carbon. Data from such experiments are needed for scientific advances in both stockpile stewardship and planetary science. This intensive sequence of science experiments required the design, production, and qualification of eight types of targets and seven new experimental platforms (combinations of targets and supporting hardware and diagnostics).

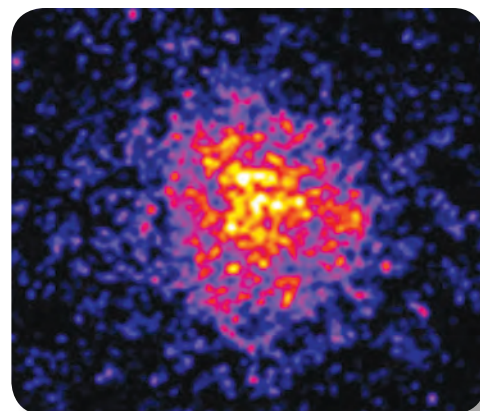
Transforming NIF into a User Facility

LLNL took steps to transition NIF to routine facility operations as a user facility by the end of FY2012, establishing a process for allocating NIF facility time across all mission areas. A NIF Governance Plan, to be approved by NNSA, was drafted and reviewed by members of the user community. Facility maintenance and reconfiguration activities readied NIF for subsequent NIC experiments with higher neutron yield and for non-ignition weapons science and other mission-driven tests. Improvements were made to the laser to enhance operating performance and reliability, and several new diagnostics were installed. During FY2011, NIF demonstrated operations at 1.6 MJ and will soon reach its design goal of 1.8 MJ. Also, NIF is now authorized to conduct high-yield experiments (up to 10^{19} neutrons).

Exploring LIFE

The Laboratory is pursuing Laser Inertial Fusion Energy (LIFE) as an enduring source of baseload clean energy. In 2011, the LIFE power plant concept evolved to become a highly modular design approach for operational reliability. It takes advantage of substantial prior technology development and uses conventional materials to reduce costs and technical risks. The design was developed in close consultation with the electric utility industry, a wide range of vendors, power plant

licensing experts, environmental groups, and LLNL technical partners. As work on LIFE continues, the Electric Power Research Institute and the National Research Council are examining the cost effectiveness and scientific principles behind LIFE. After achieving ignition at NIF, the next step toward LIFE will be an integrated technology development program leading to construction of a demonstration plant in the 2020s.



Neutron emission data collected from a target implosion experiment conducted in August 2011 revealed that scientists were able to generate a small, round core of highly compressed DT fuel.

Global Security

Providing expertise and systems solutions to counter proliferation, defend against terrorism, support the U.S. military, and enhance global stability

The Laboratory applies the full range of its scientific, technical, and analytical capabilities to pressing issues affecting global security. Researchers develop advanced technologies to preclude the proliferation or use of weapons of mass destruction and enhance the capabilities of the U.S. military. Technical experts support international engagement in nonproliferation, threat reduction, and nuclear test monitoring, while innovations in imagery analysis and cyber defense help strengthen national security in a networked world.

LLNL's Persistics system can turn overhead video imagery data (left) into 3D images with an unprecedented level of detail (right).

Persistics "Eye in the Sky"

Livermore developed a new technology to help the U.S. Department of Defense and other agencies handle the enormous volume of overhead video imagery data collected by satellites and aerial vehicles. The Persistics system makes it possible to monitor tens of square kilometers of terrain from the skies, with sufficiently high resolution for tracking people and vehicles for many hours at a time. In 2011, LLNL delivered a high-performance computing cluster to the National Geospatial Intelligence Agency with a novel high-speed processing pipeline that compresses unchanging background by a factor of a thousand and extracts moving vehicle tracks and patterns of activity, increasing analyst productivity and enhancing the protection of U.S. forces on the battlefield.

Mitigating Traumatic Brain Injury

LLNL found that soldiers could reduce the severity of traumatic brain injury by wearing one-size-larger military helmets fitted with thicker pads. In a study for the U.S. Army and the Joint IED (Improvised Explosive Device) Defeat Organization (JIEDDO), Laboratory researchers used experiments and computational simulations to study the response of various helmet pad systems to battlefield-relevant blunt and ballistic impacts. JIEDDO continues to work

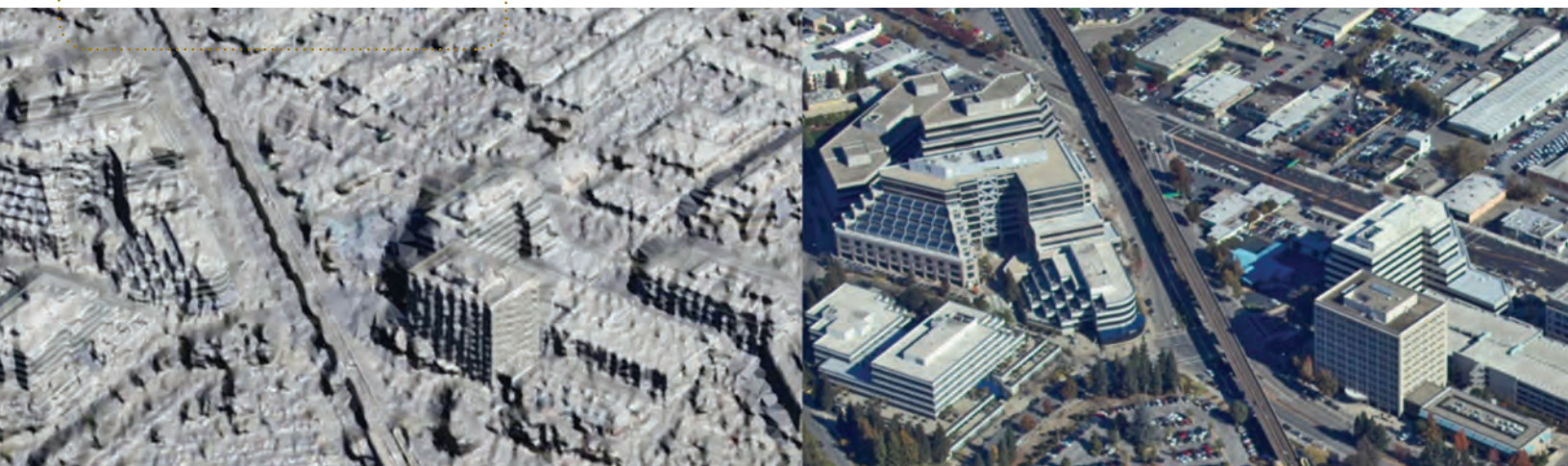
with LLNL to examine thicker pad systems with the goal of further protecting soldiers against impact and against blast injuries caused by IEDs.

Supercomputing and Cyber Security

Using the Laboratory's supercomputers, researchers devised a way to look for suspicious cyber behavior, similar to the way antivirus software searches for suspicious content. The technology relies on an agent on every desktop—a tiny, nearly invisible application that takes up almost no memory—and uses one of LLNL's supercomputers to build a software model of the activity on all the Laboratory's 40,000 unclassified computers. With this new technology, cyber security analysts can monitor computer behavior to detect the "fingerprints" of hackers and if a computer starts to behave suspiciously, they can quickly disconnect it from the network.

Test-Ban Treaty Support

LLNL was the lead organizer of a technical workshop, held in October 2010 at NNSA's Cooperative Monitoring Center in Amman, Jordan, to strengthen test-ban treaty implementation capabilities in the Middle East. At the meeting, technical experts from 12 countries and the Comprehensive Nuclear-Test-Ban Treaty Organization developed a wide-ranging agenda for building technical capabilities and enhancing





The Laboratory helped organize a workshop in Amman, Jordan, to strengthen test-ban treaty implementation capabilities in the region.



During an April 2011 visit to LLNL, Russian laboratory directors toured NIF and the High Explosives Applications Facility.

transparency in the region. In November 2010, several Livermore technologies, including antineutrino detection, a novel application of radiofrequency identification, and a new technique for detecting fuel rod diversion, were featured at the 11th International Safeguards Symposium, hosted by the International Atomic Energy Agency in Vienna, Austria.

Sub-Three-Minute PCR and Other Detection Advances

Laboratory scientists made technology breakthroughs for biological, chemical, and nuclear detection. A new PCR (polymerase chain reaction) device achieved 30-cycle (billion-fold) amplification of target DNA in as little as two minutes and 18 seconds. The extremely fast thermal cycling (less than 2.5 seconds per cycle) is made possible by the use of a porous material and a thin-film resistive heater. For chemical detection, a novel nanosensor was fabricated that relies on semiconductor nanowires and does not need batteries. Researchers also demonstrated a new laser-based technology called resonance ionization mass spectrometry that can rapidly detect ultratrace levels of uranium or plutonium isotopes. In addition, two new scintillator materials were developed that perform almost as well as standard materials for neutron and gamma-ray detection but offer safer, more environmentally friendly manufacturing and considerably lower cost.

Nuclear Material Protection

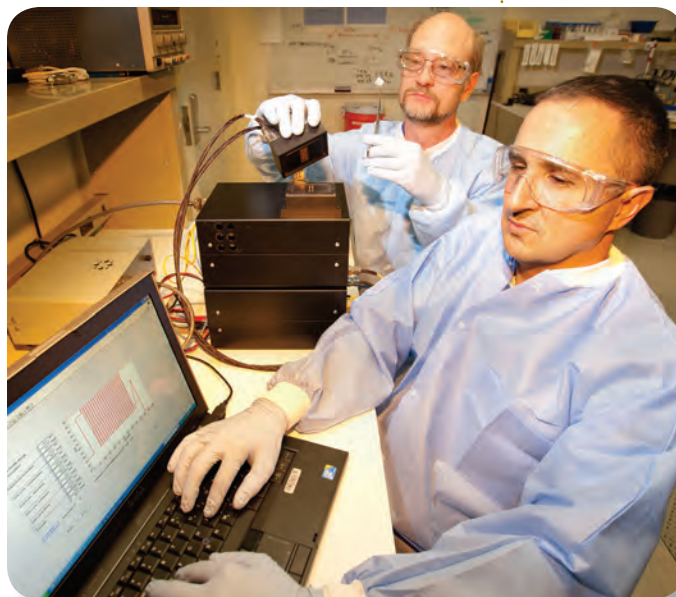
The Laboratory oversaw the recovery of 90 high-curie radioisotope thermoelectric

generators from unsecured remote locations in the Russian Far East, 46 of which were transported to Moscow for disassembly, 18 placed in secure storage awaiting transport to Moscow, and 26 disassembled and transported to the Mayak facility for long-term storage. LLNL also assisted eight African countries (Burkina Faso, Democratic Republic of the Congo, Gabon, Ghana, Mauritius, Namibia, Republic of the Congo, and South Africa) with security upgrades to nuclear facilities, secure storage facilities (including a new source storage facility in Ghana), and inventory support.

National Plan for Nuclear Forensics

An LLNL physicist co-led the development of the first-ever national strategic five-year

plan for nuclear forensics and attribution. The effort required integrating numerous agencies and multiple mission areas, as well as drafting significant portions of the document and coordinating 19 rounds of interagency reviews. The Congressionally mandated plan describes the Administration's policy, analytical, and budgetary plans and priorities for the next five years for enhancing the nation's capabilities in nuclear forensics and attribution. The plan was signed by the President and submitted to Congress on April 30, 2010.



LLNL engineers developed a new biodetection instrument that can process DNA samples in less than three minutes. This device has potential for widespread use in public health, food safety, and biosecurity.

Energy and Environment

Helping meet the nation's and the world's energy needs while promoting environmental sustainability and mitigating climate change

Energy and environmental security are key to national security and global stability. To this end, the Laboratory strives to devise ways to reduce the environmental impact of fossil fuels, increase the efficiency and usability of alternative energy resources, and create new energy sources for the future. LLNL researchers also evaluate the implications of energy use decisions, develop technologies for mitigating the environmental impacts of energy use, and investigate the processes that influence global climate and drive climate change.

Hyperion and other Laboratory high-performance computing resources are being applied to complex energy problems, such as state-level simulations of the energy grid and detailed modeling of energy usage in large commercial buildings.

HPC for Energy Challenges

Livermore high-performance computing (HPC) capabilities were applied to address challenges involved in meeting California's goal that one-third of the state's energy come from renewable resources by 2020. Working with members of the utility industry and a utility software company, Laboratory computer scientists adapted a commercial energy system simulator code to run on LLNL's supercomputers, optimized some of the mathematics, and modified the system to run simulations in parallel. When combined with the Laboratory's HPC processing power, the simulator now runs thousands of scenarios in a day, compared to the several days required previously to compute a single scenario. This advance in simulation capability

makes it possible to more accurately model the relationships and consequences of changes in the state's energy system.

Also this year, LLNL partnered in the Greater Philadelphia Innovation Cluster for Energy Efficient Buildings (GPIC), through which Laboratory HPC expertise and resources are being used to develop a detailed modeling capability for energy usage in commercial buildings. In addition, LLNL partnered with the California investor-owned utilities in developing the proposal for a California Energy Systems for the 21st Century (CES-21) initiative, which aims to apply HPC to address challenges facing the utilities. These include the increasing use of renewable energy resources, growth in electric transportation, and the need to protect the state's electric grid from cyber attack. The utilities have presented the CES-21 proposal to the California Public Utilities Commission.

Promising Carbon Capture Process

Recent tests indicate that it may be possible to speed up a natural process for removing carbon dioxide (CO₂) from the atmosphere to the benefit of the oceans. Specifically, an LLNL

researcher conducted a series of laboratory-scale experiments to find out if a seawater/limestone (calcium carbonate) scrubber could effectively remove CO₂ from a natural gas power plant's flue stream to form dissolved calcium bicarbonate, which could be "stored" in the ocean and help offset ocean acidification. Although further research is needed at larger scales and in more realistic settings, such a process could be highly effective at coastal power plants where massive quantities of seawater used for cooling could be easily reused for the CO₂ mitigation process.

Earth System Grid

LLNL's Program for Climate Model Diagnosis and Intercomparison continued its management of the Coupled Model Intercomparison Project, Phase 5 for the international World Climate Research Programme. As part of this effort, Livermore leads the Earth System Grid Federation, which stores and distributes terascale data sets from coupled ocean-atmosphere global climate model simulations from modeling centers around the world. In FY2011, LLNL launched the Earth System Grid Center for Enabling Technologies, the culmination of a five-year DOE SciDAC (Scientific Discovery through Advanced Computing) project. This major new capability allows users to access, analyze, and visualize more than half a petabyte of climate data (from both models and observations) using a globally federated collection of computers and software. The system is currently serving more than 25,000 users and supports international climate model intercomparison activities as well as projects for DOE and other U.S. federal agencies.

NARAC Response to Fukushima

The National Atmospheric Release Advisory Center (NARAC), located at and operated by LLNL, provided critical guidance during the Fukushima nuclear reactor crisis. NARAC was activated on March 11, 2011, after a massive tsunami hit the east coast of Japan and knocked out power to the Fukushima reactor cooling systems, resulting in damage to reactor cores and the release of radioactivity. NARAC generated a steady stream of atmospheric dispersion predictions, plume projections, and radiation dose estimates, continually updating them as meteorological conditions changed and new information about the reactors' status was received. The projections were used by the



A Livermore chemist synthesizes functional mimics of carbonic anhydrase, a naturally occurring carbon dioxide-capturing enzyme, with the goal of developing a compound that can efficiently capture carbon dioxide from industrial plant emissions.



Researchers at NARAC (shown here) and across the Laboratory worked around the clock for weeks providing technical support in response to the March 2011 earthquake, tsunami, and nuclear reactor disaster in Japan.

U.S. government in advising American citizens in Japan about protective actions, by the U.S. Department of Defense in conducting disaster relief operations, and by the government of Japan in developing guidelines for population relocation. During the height of the crisis, NARAC operated around the clock for 22 days. By the time active operations were halted in mid-May, NARAC had logged more than 5,000 person-hours and produced more than

300 projections and analyses. The NARAC computer modeling system, containing millions of lines of code, and the NARAC web system, which received some 3 million hits, functioned 24 hours a day, seven days a week, for three months with no crashes or downtime. Equally gratifying was the fact that subsequent field data validated the accuracy of NARAC's projections of the amount of radioactivity released and its dispersion.



LLNL launched several new wind energy projects in FY2011, including collaborations to evaluate the feasibility of deep ocean wind power generation and to model the wakes that form behind wind turbines.

Photo courtesy of Vattenfall.

Science and Technology

Expanding the frontiers of scientific knowledge and advancing the technological state of the art to solve problems of national and global importance

Science and technology are central to solving many of the most serious problems facing the nation and the world. They are also crucial to exploring and understanding the cosmos and decoding the mysteries of life. Research using LLNL's world-class experimental and computational resources and multidisciplinary scientific expertise has led to an exciting array of discoveries and innovations, many of which have been transformed into products and capabilities that created new industries and helped strengthen the U.S. economy.

Lytic proteins that destroy bacterial cell walls hold promise as a way to combat antibiotic-resistant infections. LLNL scientists mine the genomes of bacteria that pose public health and biosecurity concerns to identify the genes for these specific proteins and then synthesize the proteins in the laboratory.

Attacking Bacteria through Their Genes

Researchers discovered a way to use a bacterium's genes against itself, potentially solving the problem of antibiotic resistance. They identified the specific genes that encode lytic proteins—those that nick the cell wall, an essential step in cell division and reproduction—and synthesized the proteins in the laboratory. When the purified proteins are introduced to the exterior of the bacterial cells, they cause the complete destruction of the cell walls. Each lytic protein is almost unique to each bacterial

species, so the purified protein targets only that particular species and a few very closely related “near neighbors.” Because these proteins are essential to the bacterial life cycle, bacteria are extremely unlikely to become resistant to them. Equally important, since human cells lack the particular cell wall components that the lytic proteins target, these proteins cause no harm to human cells. Purified proteins have been provided to the Centers for Disease Control and Prevention and the U.S. Army Medical Research Institute for Infectious Diseases for testing related to their potential use in public health and biosecurity.

New Insights into Obesity and Diabetes

Carbon-14 analyses at the Center for Accelerator Mass Spectrometry (CAMS) focused on two significant public health issues—obesity and diabetes. One study revealed that the average turnover rate of fat is 25 percent longer in obese





Carbon-14 analyses, which are conducted at the Center for Accelerator Mass Spectrometry, revealed significant differences in fat metabolism for obese and normal-weight persons. Here, a researcher is shown preparing samples for analysis.

people than in normal-weight people. It also showed that while fat storage and removal rates balance in non-obese people, the amount of fat stored each year increases for obese people—clear evidence that normal-weight and obese people have physiological differences in how their bodies develop and maintain fat. Another study looked at the turnover and longevity of insulin-producing beta cells. Whether beta cells replicate after birth has been an open issue and is central to the design of therapies for diabetes. CAMS measurements of the amount of carbon-14 in beta cell DNA revealed that no new beta cells are created after age 30, thus limiting the body's ability to increase insulin production to compensate for aging or to meet increased demand because of weight gain.

LLNL Spectrometer Orbiting Mercury

On March 17, 2011, the National Aeronautics and Space Administration's (NASA's) MESSENGER spacecraft entered into orbit around the planet Mercury. Among the spacecraft's instruments is a Laboratory-designed gamma-ray spectrometer (GRS) that is characterizing emissions from the planet to determine the composition of Mercury's surface materials. In developing the GRS, LLNL scientists and engineers had to find a way to field an instrument that could withstand the extreme heat from both Mercury and the Sun while maintaining the germanium crystal at cryogenic temperatures. Their solution was a thermal and mechanical cooling design that keeps the germanium crystal at minus 200 degrees Celsius while rejecting 98 percent of the heat from the broiling surroundings.

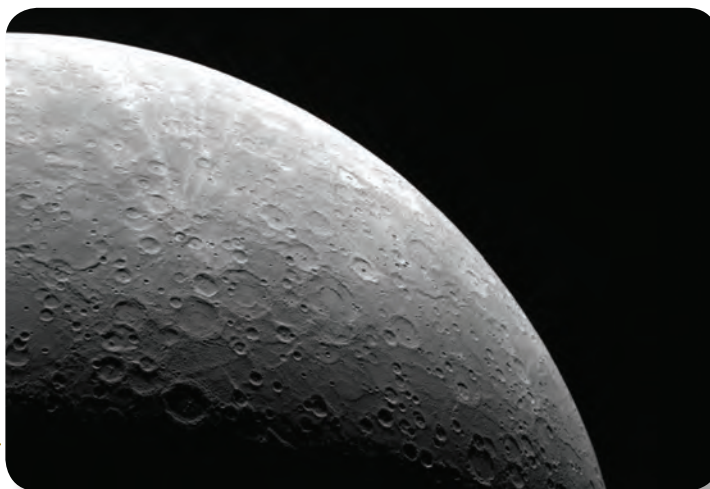
Formation of the Solar System

Precise isotopic analyses conducted at LLNL shed new light on how the solar system formed and the age of the moon and Earth. In one project, Laboratory scientists and collaborators measured the oxygen isotopes of a calcium aluminum-rich inclusion (CAI) in a piece of the Allende meteorite. CAIs are some of the oldest objects in the solar system, and understanding how they formed provides insight into the formation and evolution of the solar system. The researchers found that this CAI had a very turbulent beginning, traveling far from where it originated through multiple regions of the

protoplanetary disk that surrounded the Sun when it was very young. In another project, analyses of the isotopes of lead, samarium, and neodymium in lunar crustal rocks revealed that the moon and Earth are younger than previously thought, 4.36 billion years old instead of the earlier estimate of 4.5 billion, making them younger cousins to Mars by about 165 million years.

Searching the Cosmos

Laboratory scientists were awarded hundreds of hours of time on two state-of-the-art astronomical observing platforms. One team



Data gathered by the MESSENGER spacecraft's gamma-ray spectrometer (designed by LLNL) about the surface composition of Mercury are providing clues to how the solar system's smallest planet formed. Images of the planet were taken in the summer of 2011 as the spacecraft flew high above Mercury.

Photo courtesy of the National Aeronautics and Space Administration/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

Science and Technology



LLNL scientists were awarded 890 hours of observing time with the Gemini Planet Imager over the next three years. Here, the moon rises over the Gemini South telescope on Cerro Pachon, Chile.

Photo courtesy of Gemini Observatory.

won 890 hours of viewing time with the Gemini Planet Imager (GPI) to detect and image extrasolar planets. LLNL has been working for five years to build systems for GPI, and Laboratory researchers will now be some of the first to use the new instrument. The 890-hour allocation represents about 10 percent of the telescope's time for three years. Another research team was awarded 766 hours of observing time on NASA's Spitzer Space Telescope to study galaxies located 5 to 10 billion light years away from Earth to learn how they formed and how they have changed and grown over time.

ALICE Collaboration

Livermore installed and is operating the 10-teraflop/s Green Linux Compute Cluster as part of a joint LLNL–Lawrence Berkeley National Laboratory (LBNL) effort to provide primary computing and storage resources for data from the ALICE (A Large Ion Collider Experiment) experiment at the Large Hadron Collider (LHC). This cluster, which is used by more than 1,000 researchers worldwide, is the third largest in the international ALICE collaboration. ALICE is one of the four principal particle detector experiments on the LHC and collects roughly 10 terabytes of

data per day, 10 percent of which is transmitted from the LHC in Switzerland to LLNL and LBNL over DOE's Energy Science Network. ALICE is designed to measure the particles resulting from collisions of lead nuclei traveling at nearly the speed of light. Scientists hope these collisions will recreate the quark–gluon plasma that first existed nearly 14 billion years ago, millionths of a second after the Big Bang, and that the data generated will provide clues as to the fundamental nature of the matter that makes up the universe.

New Approach to Idea Generation

The Laboratory launched a pilot program using the Spigit online application for “crowdsourcing” solutions to real problems in short periods of time. Spigit works by presenting a problem and asking the crowd (of Laboratory employees) to post their ideas and to comment and vote on the ideas of others. During the first three months of the pilot, seven challenging problems were posed related to biodefense, cyber security, nonproliferation, energy, materials, and defense. Spigit clearly demonstrated its ability to speed the collaboration process, surface new ideas, and connect researchers to expertise outside their immediate networks.

A Super Debugging Tool

Livermore researchers and their collaborators from the University of Wisconsin at Madison and the University of New Mexico developed a new tool to help meet the enormous challenge of debugging applications designed to run efficiently on supercomputers that, in the near future, will have millions of cores working in parallel. Current debugging tools were not designed to scale to such sizes and are impractically slow. The Stack Trace Analysis Tool (STAT) can identify errors in code running on today's largest computers and will work on even bigger machines. It works by detecting and grouping similar processes at suspicious points in an application's execution. STAT achieves this grouping by dynamically examining the state of each process and extracting the call stacks—the sequence of function calls—that led to the current point of execution. Because it gathers stack traces across the entire application, STAT provides a global view of what every



LLNL is part of the international collaboration at the Large Hadron Collider, where particles are smashed together at unprecedented energies to investigate the very nature of matter and the origins of the universe.

Photo courtesy of the European Organization for Nuclear Research.

process is doing, so users can identify a small yet representative subset of tasks on which to conduct more thorough analysis.

Award-Winning Technologies

The STAT highly scalable debugging tool (see above) is one of two Livermore-developed technologies that received an R&D 100 Award in 2011, bringing the Laboratory's total to 137 such awards since 1978. The other winner, the Serrated Light Illumination for Deflection-Encoded Recording (SLIDER) system, captures the time history of burning plasma in a fusion target with extremely fine time resolution and ultrahigh dynamic range. LLNL also received awards from the Federal Laboratory Consortium for Excellence in Technology Transfer for an intracranial hematoma monitor based on LLNL's ultrawide-band radar technology, a robotic DNA detection instrument for ocean research and environmental monitoring, an adaptive optics tomography system for retinal imaging, and a line of antibody-producing cells widely used in heart disease and cancer research.

MOU with Angel Investor Network

LLNL signed a Memorandum of Understanding (MOU) with the Keiretsu Forum, the world's largest network of angel investors (investors who provide funding for startup companies). Through this collaboration, the forum's expertise in structuring, investing in, and implementing "go to market" strategies will be applied to the Laboratory's portfolio of technologies available for commercialization. Initial emphasis is focused on developing a process for evaluating technologies and market opportunities and moving forward with those deemed most promising.

Entrepreneurship Academy

Livermore hosted an Entrepreneurship Academy this summer in which 16 San Francisco Bay Area college students working in four teams gained firsthand experience in developing business plans for commercializing LLNL technologies. To make the program as realistic as possible, a number of entrepreneurs who have successfully commercialized Laboratory-developed technologies were brought in to

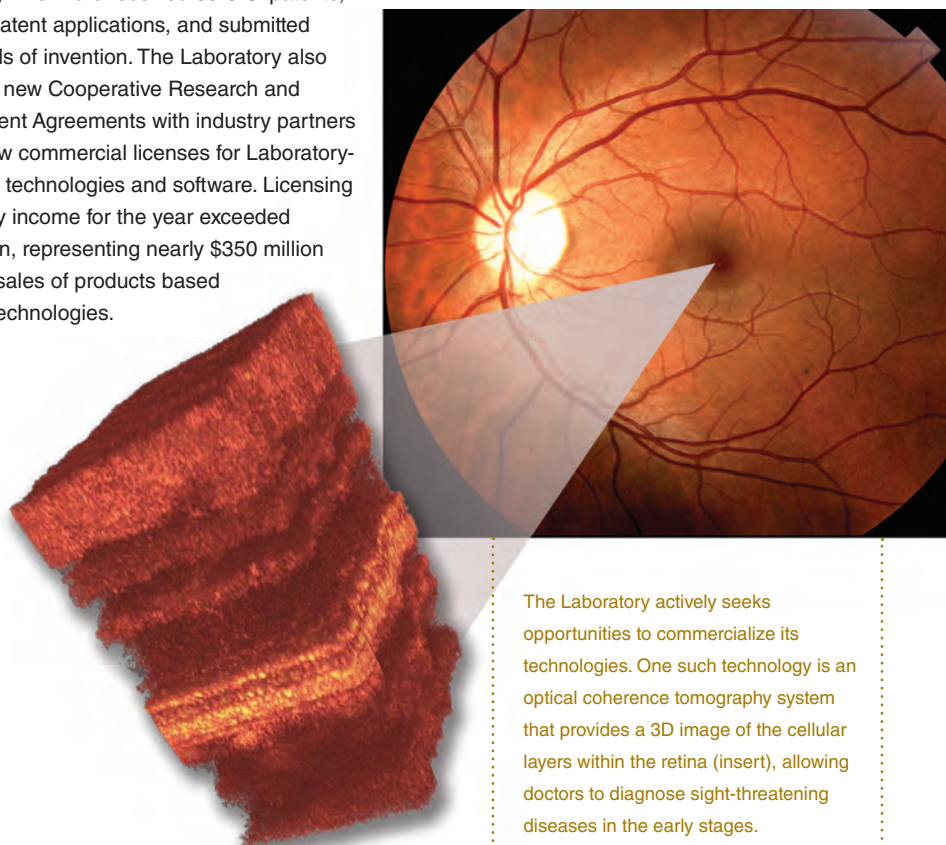
advise the students and judge their business plans. Three teams chose technologies related to health care, and the fourth selected a fuel-cell technology. The winning proposal was for a rapid diagnostic for sexually transmitted diseases that could be used like an early pregnancy test; the team is taking steps to turn their plan into an actual business endeavor.

Industrial Partnering Statistics

In FY2011, Livermore received 60 U.S. patents, filed 123 patent applications, and submitted 164 records of invention. The Laboratory also signed six new Cooperative Research and Development Agreements with industry partners and 24 new commercial licenses for Laboratory-developed technologies and software. Licensing and royalty income for the year exceeded \$8.4 million, representing nearly \$350 million in annual sales of products based on LLNL technologies.



The Dynamic Transmission Electron Microscope at LLNL allows scientists to observe in nanoseconds and at the nanometer scale basic phenomena at the heart of chemistry, biology, and materials science such as chemical reactions, structural deformations, and phase transformations.



The Laboratory actively seeks opportunities to commercialize its technologies. One such technology is an optical coherence tomography system that provides a 3D image of the cellular layers within the retina (insert), allowing doctors to diagnose sight-threatening diseases in the early stages.

Safety, Security, and Sustainability

Demonstrating safety and security excellence and sustainable environmental stewardship in all Laboratory activities

LLNL continuously strengthens its commitment to environment, safety, and health (ES&H) and security. Best practices are implemented throughout the Laboratory, driven both from the top down and from the bottom up. The safety of employees and the public is ensured through prudent risk management coupled with active measures to prevent accidents. LLNL operations implement sustainable best practices and meet the highest standards in security.

improvement of LLNL's performance in ES&H and enhances the Laboratory's ability to work with other federal agencies.

Also in 2011, LLNL safely disposed of more than 300 containers of high-hazard chemicals that are no longer needed, eliminating the risks and costs associated with extended storage. All low-level nuclear waste disposal targets were met on or ahead of schedule. In the area of explosives safety, the Laboratory and NNSA's Livermore Site Office (LSO) conducted nearly 100 ES&H-related assessments with no major findings. In addition, a team of environmental scientists used the Laboratory's extensive groundwater modeling capabilities to assess the sufficiency of existing monitoring wells for evaluating the extent and impact of contaminants at Site 300, LLNL's remote testing site. This work demonstrated that additional monitoring wells were not needed, resulting in a cost avoidance of approximately \$5 million.

Effective ES&H

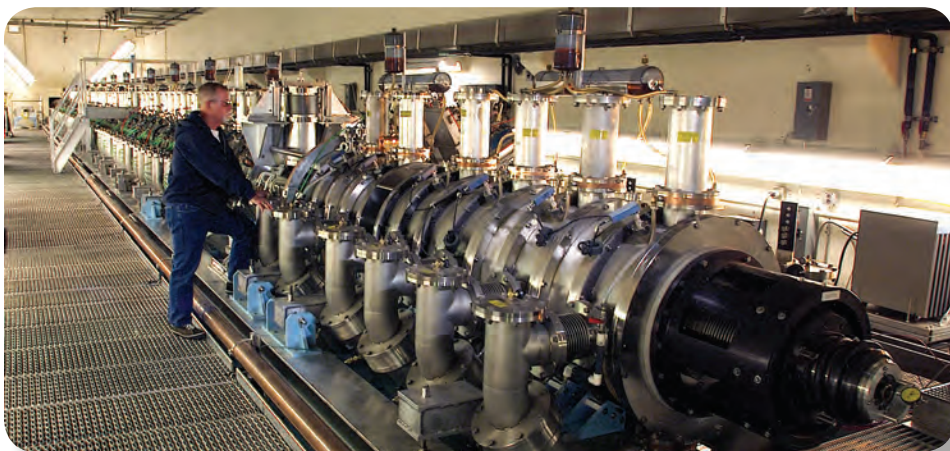
In 2011, the Laboratory received Occupational Health and Safety Assessment Series (OHSAS) 18001 accreditation for its Occupational Health and Safety Management System (OHSMS), which incorporates LLNL's Integrated Safety Management System and provides an overarching framework recognized by the International Organization for Standardization (ISO). In addition, steps are being taken to integrate OHSMS with LLNL's ISO-14001-accredited Environmental Management System, which provides a systematic approach to identifying and reducing the environmental impact of Laboratory activities. ISO-14001 accreditation has been in place for two years, and the program successfully passed two surveillance audits this year. Accreditation by OHSAS and ISO facilitates the continuous

Sustainability Campaign

The Laboratory launched a major campaign in September to elevate employee awareness of better sustainability practices. The effort builds on recent LLNL environmental stewardship accomplishments. For example, greenhouse gas emissions have been reduced by more than 15 percent over the last three years, saving 40,000 equivalent metric tons of CO₂. Energy consumption has decreased by 55 million kilowatt-hours or 12.8 percent compared to 2003 usage. Water consumption has been reduced by 33 million gallons per year, and alternative-fuel vehicles comprise 75 percent of the Laboratory fleet, surpassing the goal for FY2015. The new sustainability campaign aims to achieve further reductions, which are important to offset expected power needs as NIF's experimental pace increases and Sequoia comes on line. Although Sequoia has been ranked by Green500 as the world's most energy-efficient supercomputer, its dramatically greater computing capability will increase the Laboratory's power consumption.



In 2011, an extensive internal communications campaign served to heighten employee safety awareness, call attention to effective safety practices, and explain the value of OHSMS 18001 and how it complements the Laboratory's Integrated Safety Management System.



LLNL received an Environmental Sustainability (EStar) award from DOE for a project to minimize the use and release of sulfur hexafluoride (SF_6), an extremely potent greenhouse gas that prevents damage to high-voltage equipment. Usage of SF_6 at the Flash X-ray machine at Site 300 has been reduced from about 920 pounds per year to less than 115 pounds.

Site Security

LLNL revised its Site Safeguards and Security Plan, which was approved by LSO in record time. Successful implementation of numerous security reforms in the areas of physical protection and information security improved mission effectiveness and cost efficiency. The Laboratory also aggressively managed the correction of self-identified issues that arose during the year. At the end of FY2011, 90 percent of the Laboratory's inventory of special nuclear materials requiring the highest level of protection had been shipped to other NNSA locations. These shipments, which are part of NNSA's efforts to consolidate high-security nuclear materials at only a few sites, will be completed in FY2012. A detailed Security Program Plan has been developed for post-2012 security operations and activities to implement the plan are being pursued.

Tops in SWAT

The Laboratory's Special Response Team continued its tradition as a top-tier performer in special weapons and tactics (SWAT) competitions. The Livermore team finished a close second out of 33 teams in this year's Connecticut SWAT Challenge and took first place in the individual handgun and rifle competitions.

Events included hostage rescue, vehicle assault, marksmanship, obstacle course, and a 4.8-mile physical marathon challenge. The Laboratory team also took fourth place out of 29 teams in the annual Urban Shield exercise, sponsored and managed by the Alameda County Sheriff's Office. Urban Shield is one of the largest emergency preparedness exercises in the nation and draws SWAT teams from across the country and as far away as the Middle East.

Cyber Defense

The Laboratory expeditiously completed NNSA-mandated information security reforms and revised its Cyber Security Program Plan. In addition, LLNL hosted a cyber security exercise that brought together 26 elite cyber security responders from NNSA sites around the country. In this first exercise of its kind, the participants took part in three days of "cyber combat" to repel a would-be intruder and

defend against the kinds of attacks that are being seen with increasing frequency. In addition to providing critical training, the exercise facilitated team building, which is extremely valuable because cyber attacks often target multiple institutions necessitating a coordinated response.



Responding to employee suggestions, the Laboratory launched a pilot comingled recycling and composting program as part of its "Going Green" initiative. Recycling bins are in the Laboratory's cafeterias and a growing number of buildings across the site.



Officers from the Laboratory's SWAT team took second place and dominated shooting events at this year's Connecticut SWAT Challenge, considered the toughest SWAT competition in the country.

Management and Operations

Guiding the Laboratory's future course, managing the workforce, improving work processes and business practices, and achieving cost efficiencies

Continuous improvement in management, operations, and business practices positions LLNL for success as a broad national security laboratory. Strategic program development—together with investments in infrastructure and the workforce—ensure that the Laboratory has the capabilities necessary to serve the nation now and in the future.

New Laboratory Director

On October 27, 2011, Dr. Penrose (Parney) C. Albright was announced as the next Laboratory director, effective December 1. Albright's selection culminated a rigorous, competitive national search led by the University of California and the review and consideration of more than 200 candidates. Albright, who holds a Ph.D. in physics from the University of Maryland, has served as LLNL principal associate director for Global Security since November 2009. Prior to joining the Laboratory, he was an assistant secretary in the Department of Homeland Security, assistant director in the Office of Science and Technology Policy, senior director in the Office of Homeland Security in the White House, program manager with the Defense Advanced Research Projects Agency, and on the staff of the Institute for Defense Analyses conducting studies for the Office of the Secretary of Defense.

Strategic Program Development

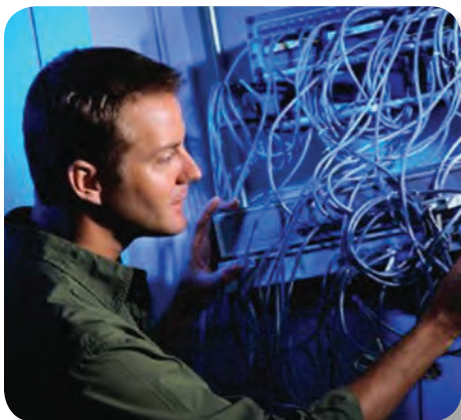
In January, the Laboratory established the Office of Strategic Outcomes (OSO) to facilitate the growth of interagency work as part of LLNL's

Dr. Penrose (Parney) C. Albright became president of LLNS and the eleventh director of the Laboratory on December 1, 2011.

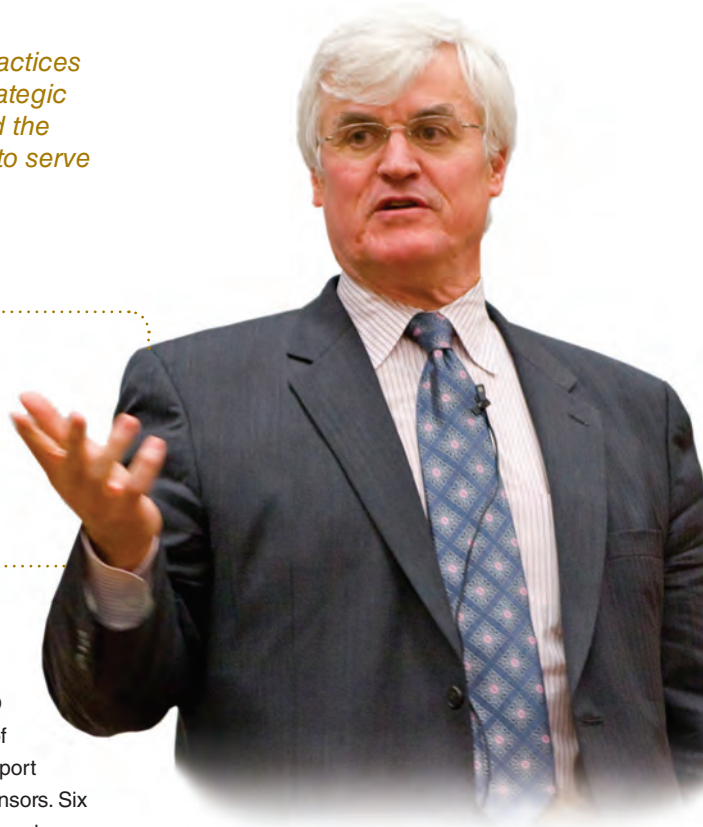
mission responsibility as a broad national security laboratory. The OSO provides oversight and coordination of a unified institutional approach to support a broad base of national security sponsors. Six OSO program directors work with Laboratory programs and employees, government agencies, industry, and academia to identify strategic opportunities where LLNL has special capabilities that can be applied to address pressing national security needs. OSO includes a mission opportunities office to improve the quality of project proposals through training programs, consultations, and hands-on assistance as well

as a business office to facilitate the proposal approval and work-initiation process.

Institutional investments in new capabilities complement strategic program development. In FY2011, the Laboratory's unclassified network backbone received a major upgrade to provide LLNL users with a 10-gigabit-per-second infrastructure. In addition, a ribbon-cutting ceremony officially opened the Advanced Composites Engineering Facility. At this newly refurbished 6,000-square-foot space, researchers are designing and testing advanced composites for applications such as low-collateral-damage (third-generation) conventional munitions and advanced flywheels for energy storage. A new 8.2-meter-tall fiber draw tower also began operations; the facility is being used to develop ribbon-shaped optical fiber lasers.



A major upgrade of the unclassified network backbone was part of continuing efforts to modernize the Laboratory's information infrastructure. Institutional investments are also targeted at physical infrastructure to maintain facilities and support missions and the S&T base.



New Facility for the Open Campus

The High-Performance Computing (HPC) Innovation Center opened for business in June. It is the first new facility at the Livermore Valley Open Campus, which is located on a 110-acre parcel on the eastern edge of the Lawrence Livermore and Sandia–California sites. The 12,000-square-foot HPC Innovation Center serves as a focal point for collaborations among LLNL experts in the application of HPC and partners in industry and academia. Collaborations are aimed at using HPC to create innovative solutions for U.S. industry in such areas as product design, development and manufacturing, the management of vast amounts of data, and the operation of complex energy and communication systems.

Workforce Training and Career Growth

The Laboratory implemented three new leadership development programs: Customer Value Creation, for all employees; Managing for Results, for first-line supervisors; and the Management Institute, for senior-level management succession candidates. These programs augment a diverse existing employee development portfolio that includes, for example, a highly successful Leadership Institute. This program, conducted in collaboration with the Haas School of Business at the University of California, Berkeley, recently graduated its second class of 40 mid-career future leaders. LLNL is also making a concerted effort to recruit new young scientists and engineers to the Laboratory. The number of postdoctoral fellows at LLNL continued to grow in 2011. More than 200 postdocs, are currently working at the Laboratory, nearly double the number from two years ago.

The Variable Compensation Program was fully implemented this year as a new tool to



Congressional representatives John Garamendi (CA–10th District, shown here with Deputy Director Tom Gioconda) and Jerry McNerney (CA–11th District) as well as local officials attended the dedication ceremony for the High-Performance Computing Innovation Center on June 30, 2011.

incentivize and reward the workforce. The program provides strategic performance bonuses to all eligible employees contributing to the overall success of the Laboratory as well as individual performance bonuses to a small subset of employees who demonstrate particularly significant contributions.

The new job classification system for professional scientific and technical staff, introduced in 2010, includes Distinguished Member of Technical Staff as a new job classification that recognizes employees who have made extraordinary scientific and technical contributions to the Laboratory and its missions. In July 2011, four senior researchers were named to this elite position: John Lindl (NIF and Photon Science), Mordy Rosen (Weapons Complex and Integration), Ben Santer (Physical and Life Sciences), and Cary Spencer (Global Security).

Improving Operations

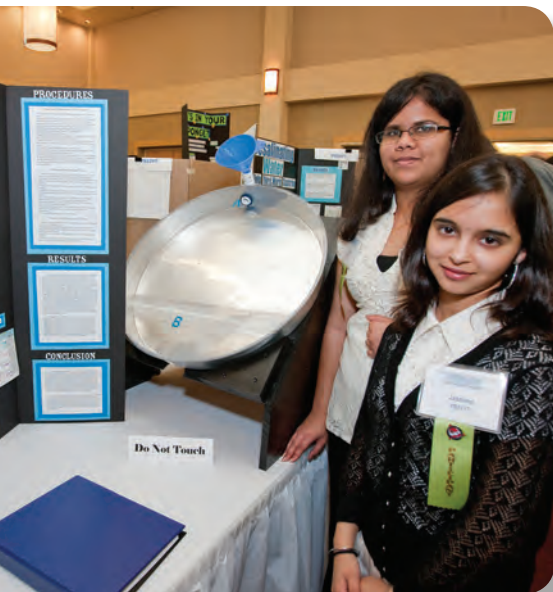
Continuous improvement efforts are engrained in LLNL's business and operations functions. For example, the Laboratory's Performance Measurement Baseline financial and project management system continues to evolve and improve through an Institutional Change Control Board. A total of 17 business system projects were completed in FY2011 to address priorities identified by the LLNL Business System Council. In addition, five process improvement projects were completed through the Lean Six Sigma program. Since 2009, 73 Lean Six Sigma Champions, 86 Yellow Belts, and 10 Black Belts have been trained and certified at the Laboratory.

The number of postdoctoral fellows at the Laboratory has nearly doubled in the past two years to more than 200. This program is important to LLNL's future because many postdocs stay on to become career employees.



Community Connections

Supporting local communities through science education and charitable giving



Two students from Gale Ranch Middle School in San Ramon presented their project, "Water Distillation by Solar Energy," at the 15th annual Tri-Valley Science and Engineering Fair.

As part of its commitment to being an integral and involved member of the community, LLNL supports a wide range of activities in science, engineering, and mathematics education. Laboratory employees generously contribute to local communities through charitable giving and volunteer efforts. In addition, the LLNS gift program provides a direct investment in community science and math education and cultural arts.

New Community College Seminar Series

The Laboratory and Las Positas College debuted a new science and engineering seminar series, "Theory to Practice: How Science Gets Done," in which LLNL researchers describe their work and answer questions about how they apply science and engineering to solve real-world problems. Four lectures were held for students and faculty, two in the fall semester and two in the spring. Topics for the first year's seminars included molecular imaging of cells and tissues, physics and engineering collaboration, bioinformatics, and the development of new medical devices.

Science on Saturday Lectures

LLNL's Science on Saturday lecture series was once again a hit with the community. More than 4,600 people attended a total of nine lectures, which were held in Livermore and Tracy. These free lectures highlight current research at the Laboratory and are presented by LLNL scientists

supported by master high-school science teachers. Topics featured in 2011 included cancer treatment, wind energy, climate change, carbon sequestration, and superheavy elements. In addition to playing to packed houses for live presentations, Science on Saturday lectures have gained considerable online attention. Lecture videos are available on the University of California Television Web site, on YouTube, and on the iTunesU website. This past year alone, Science on Saturday lectures had more than 2 million downloads, and iTunes selected the Science on Saturday series as a "Noteworthy" feature on iTunesU.

15th Annual Science and Engineering Fair

Participation in the 2011 LLNL-sponsored Tri-Valley Science and Engineering Fair increased by 30 percent over the previous year, with 413 students from 22 schools in Danville, Dublin, Livermore, Pleasanton, San Ramon, and Sunol presenting 262 projects in biology, chemistry, computer science, engineering, and physical science. The projects were judged by area science teachers and working scientists, many of them LLNL researchers. The senior and junior division sweepstakes winners went on to compete, respectively, in the Intel International Science and Engineering Fair and the California State Science Fair.

Teacher Research Academies

A total of 118 current and pre-service science teachers participated in LLNL's Teacher Research Academies in summer 2011. Through this program, teachers choose to work in one of three disciplines (biotechnology, energy and environment, or fusion and astrophysics) and learn new techniques for incorporating science



Every summer, LLNL hosts Teacher Research Academies in which science teachers learn new tools and techniques to enhance their classes. Here, teachers in the fusion and astrophysics section study the chart of nuclides.



The Laboratory's booth at the first annual USA Science and Engineering Festival, held on the National Mall in October 2010, was a hit with kids of all ages. Exhibits featured a 3D video of NIF and an interactive energy-climate simulation.

research into their classes. Senior teachers also have the opportunity to work for several weeks as members of Laboratory research teams to gain firsthand knowledge about how scientific research is actually conducted. In April 2011, a Tracy High School science teacher who has participated in academies for the past several years and is a regular Science on Saturday copresenter was recognized with an Award for Excellence in Science Teaching from a San Joaquin-area private philanthropic foundation.

Participation at USA Science Festival

More than 10,000 visitors, often crowded four and five deep, stopped by LLNL's booth at the inaugural USA Science and Engineering Festival, held in October 2010 on the National Mall in Washington, D.C. The Laboratory's exhibit featured an energy theme, with a 3D video that flew viewers through the National Ignition Facility and a climate simulation that challenged players to meet 21st-century energy needs while minimizing carbon emissions. The LLNL climate simulation, which made its debut at the USA festival, is believed to be the first such learning tool based on real energy data and an actual climate model used by international climate scientists. Following the festival, a Web version of the LLNL climate simulation was posted on the Laboratory's Web site for students, teachers, and the general public.

Record HOME Total

For the second year in a row, the Laboratory's HOME (Helping Others More Effectively) campaign raised more than \$3 million for nonprofit organizations in the Tri-Valley, San Joaquin Valley, and greater San Francisco Bay Area. Employee donations together with \$1 million in matching funds from the Laboratory's manager, LLNS, brought the total FY2011 contribution to an astounding \$3,428,103—the largest amount ever raised in the campaign's 36-year history.



Lawrence Livermore National Laboratory
Helping Others More Effectively

Every year near Halloween, the Run for HOME kicks off the Laboratory's annual fundraising campaign for area nonprofits. This year's campaign raised a record-setting \$3.4 million.

Workforce Recognition

Acknowledging exceptional performance and expertise

LLNL's challenging mission requires a workforce of talented, skilled, and dedicated employees. The numerous awards and honors received by Laboratory personnel are clear recognition of their excellence and the value of their contributions.



Edward Teller Medal

Bruce Remington (left) was awarded the 2011 Edward Teller Medal. Remington was honored for his work in inertial confinement fusion, laboratory astrophysics, and high-pressure materials science and his role in developing an international effort in high-energy-density laboratory astrophysics.



Presidential Early Career Award

Greg Bronevetsky received a Presidential Early Career Award for Scientists and Engineers for his work in advancing the state of the art in high-performance computing. This award recognizes exceptional scientists and engineers in the early stages of their careers.

NNSA Excellence Medals

Two Laboratory employees were recognized for their contributions to the recently signed and ratified New Strategic Arms Reduction Treaty (New START). John Luke was awarded an NNSA Excellence Medal and Mona Dreicer was awarded an NNSA Silver Medal for their excellent and distinguished service in support of the negotiation and ratification of New START.



NNSA Defense Programs Awards

Two LLNL employees received NNSA Defense Programs Employee of the Quarter awards. Aaron Puzder (left) was recognized for his work on the first LLNL hydrotest at the Dual-Axis Radiographic Hydrodynamic Test facility. Chad Noble (right) was recognized for the design and analysis of a hydrotest at Site 300's Contained Firing Facility that improved understanding of an important use-control technology.



National Academy of Sciences

Ben Santer was elected a member of the National Academy of Sciences for his research on human-induced climate change. He is one of 72 new members and 18 foreign associates admitted to the academy in 2011; election to the academy is one of the highest honors that can be accorded a scientist or engineer. Santer joins eight other current and former LLNL researchers elected to the academy.



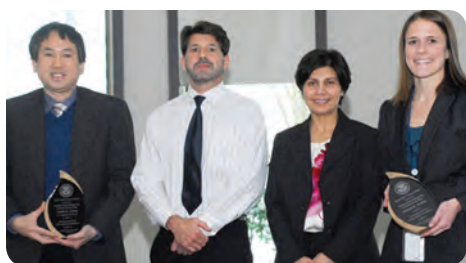
NNSA Administrator's Award

Kim Budil (center) was honored with the NNSA Administrator's Award for Excellence Medal. Budil earned this rarely bestowed award as a result of her service in Washington, D.C., as senior advisor on science research related to national security to DOE Under Secretary for Science Steven Koonin and NNSA Administrator Tom D'Agostino.

Society Fellows

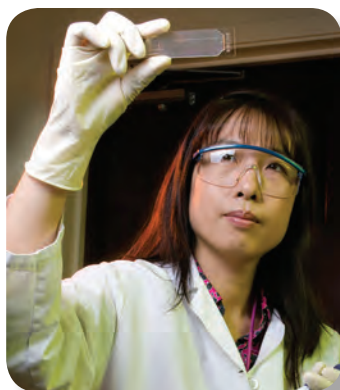
Eight Laboratory scientists were honored as fellows of professional societies. Physicists Jon Eggert, Hye-Sook Park, and Ramona Vogt together with former LLNL researcher Olgica Bakajin were elected fellows of the American Physical Society. Kennedy Reed was elected a fellow of the American Association for the

Advancement of Science. Astrophysicist Bruce Macintosh was named a 2011 fellow of SPIE, the international society for optics and photonics. Joe Nilsen and Abdul Awwal were elected fellows of The Optical Society. Climate scientist Ben Santer was elected a fellow of the American Geophysical Union.



DNDO Director's Team Award

Frank Wong (left) received the Department of Homeland Security Defense Nuclear Detection Office (DNDO) Director's Team Award for his leadership role in the development and multiagency coordination of the first-ever national strategic five-year plan for improving the nuclear forensics and attribution capabilities of the United States.



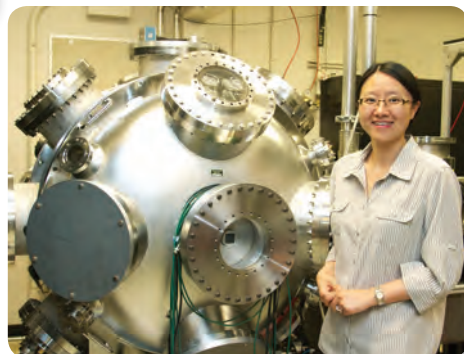
Women's Hall of Fame

Crystal Jaing was inducted into the Alameda County Women's Hall of Fame in the science category. Jaing is a codeveloper of the Lawrence

Livermore Microbial Detection Array, which has applications in law enforcement, public health, product safety, and biosecurity. She joins eight other current and past LLNL employees to be so honored.

McKay-Helm Award

John Elmer received the McKay-Helm Award from the American Welding Society for his 2009 *Welding Journal* article, "Heat Transfer and Fluid Flow during Electron Beam Welding of 304L Stainless Steel Alloy." The award is given each year for the best contribution to the advancement of knowledge and use of low-alloy steel, stainless steel, or surfacing welding metals.



Katherine E. Weimer Award

Yuan Ping was the recipient of the 2011 Katherine E. Weimer Award from the American Physical Society's Division of Plasma Physics. The award recognizes the contribution and potential of women in plasma science. Ping, a former E. O. Lawrence postdoctoral fellow, was honored for her pioneering experiments exploring the interaction of high-intensity laser light with matter.

Karl Emil Hilgard Prize

Gokhan Kirkil, together with his non-LLNL coauthors, received the American Society of Civil Engineers' 2011 Karl Emil Hilgard Hydraulic Prize for their 2009 *Journal of Hydraulic Engineering* paper entitled "Detached Eddy

Simulation Investigation of Turbulence at a Circular Pier with Scour Hole." The award is given annually to the authors of the paper judged to be of superior merit dealing with a problem of flowing water.

HPC Innovation Award

The Heavy Vehicle Aerodynamic Drag Project, led by Kambiz Salari, was one of the first recipients of International Data Corporation's new HPC Innovation Excellence Award for their use of high-performance computing to find practical ways of reducing aerodynamic drag to improve fuel efficiency of semi-trucks.

Special Fusion Power Associates Award

Chris Keane received the Board of Directors Special Award from Fusion Power Associates. He was honored for his managerial contributions to the inertial confinement fusion (ICF) technical program achievements that occurred during and beyond his tenure at NNSA and DOE and for leadership and insight that led to increased ICF research collaborations across U.S. departmental lines and internationally.



Technology Transfer Professional of the Year

The Federal Laboratory Consortium recognized Catherine Elizondo as the Technology Transfer Professional of the Year. Elizondo set a new LLNL record for transferring seven technologies to companies in a single year.

Board of Governors

Reporting on four years of progress

In the four years since Lawrence Livermore National Security, LLC (LLNS) assumed the management of the Laboratory, significant accomplishments have been made in both mission-related activities and Laboratory operations. In April, LLNL Director and LLNS President George H. Miller announced his intention to retire from his leadership role. The LLNS Board of Governors (BOG) is deeply grateful for his 40 years of service to the nation and the Laboratory. In November, Penrose (Parney) C. Albright was announced as the next LLNL director. With this transition, it seems appropriate to summarize what LLNS has accomplished at the Laboratory during the first four years of its tenure and to reflect on the challenges and opportunities that lie ahead.



Norm Pattiz

Norm Pattiz
BOG Chairman

A Vision for the Laboratory's Future

The LLNS and LLNL management team set out in 2007 with a vision of the Laboratory serving the nation as a broad national security laboratory with excellence in science and technology (S&T); an outstanding workforce; and cost-effective, safe, and secure operations. To this end, we set goals for the Laboratory to provide strong mission delivery, exceptional S&T, leadership in NNSA complex transformation, and enhanced business and operational performance. We are proud of the progress that has been made in each of these areas.

Strong Mission Delivery

As highlighted in this and previous years' annual reports, LLNL is making outstanding, sustained progress in all mission areas. Laboratory scientists and engineers achieved major breakthroughs in the understanding of a key weapons performance issue, provided valuable technical input to guide decisions about nuclear policy, developed new systems and capabilities for use in the weapon production complex, and began work to extend the lifetime of the W78 ICBM warhead. Innovative detection systems developed by LLNL are now protecting national borders and supporting international nonproliferation and counterterrorism objectives. The Laboratory has also provided advanced capabilities to the U.S. military, made great strides in initiatives to improve cyber security and space situational awareness, and developed an array of tools and technologies for energy and environmental security.



Craig Albert

Craig Albert
BOG Vice Chairman

LLNL continues to develop and deploy unique computational and experimental capabilities to address evolving national security challenges and a broad set of missions. In 2011, Livermore completed final preparations for the arrival of the 20-petaflop/s Sequoia machine, the next major advance in supercomputing. The National Ignition Facility became operational in 2009 and in 2010 was named Project of the Year by the Project Management Institute. This year, the campaign to achieve fusion ignition and burn made enormous strides and delivered outstanding science in the process.

Exceptional S&T

Innovation in S&T to meet important national needs has been the hallmark of Livermore for six decades, and the many awards and honors received by LLNL researchers in recent years provide clear evidence that the tradition continues. To ensure the enduring excellence of the Laboratory's S&T, LLNS reconstituted the external review committees and strengthened the review of Laboratory programs and scientific disciplines. Steps were also taken to enhance the career development of Laboratory scientists and engineers, and a new Professional Scientific and Technical Staff classification structure was put into place providing greater clarity of career progression.

In 2009, an S&T "roadmap to the future" was developed to ensure strategic alignment of institutional S&T investments with national priorities. Clearly defined goals in the roadmap, consistent with LLNL's strengths and missions, are guiding investments in foundational S&T capabilities and program development. This year, the Office of Strategic Outcomes was established to enhance the alignment of Laboratory program development initiatives with sponsor needs and national security missions.

Leadership in NNSA Complex Transformation

Overlap between the Boards of Governors for LLNS and Los Alamos National Security, LLC (the managing contractor for Los Alamos National Laboratory) has made it possible to

integrate or take common approaches to a variety of functions, from the use of overlapping review committees to the management of pensions and benefit programs, resulting in significant cost savings. LLNL has also contributed to NNSA cost savings through the reduction of underutilized space (more than 850,000 gross square feet since 2007) and the shipment of security category I/II special nuclear material to other sites in the NNSA complex. The deinventory process will be completed in FY2012, one year ahead of original plans.

In 2010, LLNL and Sandia National Laboratories—California established the Livermore Valley Open Campus to foster expanded opportunities for partnerships with industry and academia. In June 2011, the High-Performance Computing Innovation Center opened as the first new facility at the campus. The two laboratories have also implemented steps to lower costs by sharing some operational functions.

Enhanced Business and Operational Performance

Numerous steps have been taken under LLNS management to improve Laboratory business practices and operations. For example, LLNL has implemented a new performance baseline financial and project management system and introduced new safety and environmental management systems that meet internationally recognized standards (ISO 9001, ISO 14001, and OHSAS 18001). The Laboratory has also fully implemented a Contractor Assurance System and is maturing it to become a management assurance system that can provide a basis for more streamlined NNSA oversight.

These efforts have benefited considerably from BOG feedback and reachback to LLNS partner organizations in the form of functional management and assistance reviews. More than 80 such reviews have been conducted since 2007, including 17 in 2011. Some have led to LLNL importing commercial best practices, and others have served to validate the effectiveness and successful application of new processes and procedures. Reachback to LLNS partner organizations also enabled the Laboratory to establish a Lean Six Sigma program for continuous process improvement, adopt many

best practices, and better tackle infrastructure improvement issues.

Moving Forward

We believe that the Laboratory is poised for continuing success under the leadership of Director Parney Albright. With his unique combination of skills in science and technology, his extensive experience with interagency and Congressional interactions, and his knowledge of LLNL's extraordinary capabilities and the critical role the Laboratory plays in ensuring the nation's security, Dr. Albright and LLNL are well positioned for success in addressing the security challenges facing the nation today and in the future.



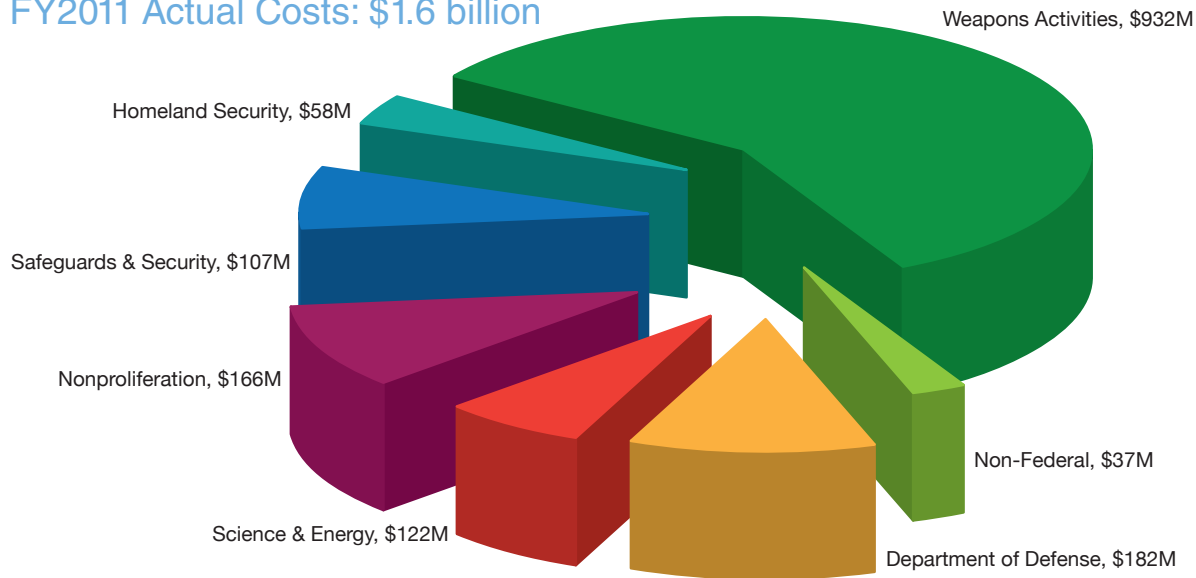
In August 2011, the NIF & Photon Science and Weapons & Complex Integration principal directorates held a joint directorate review committee meeting focused on current National Ignition Campaign implosion optimization and high-energy-density experiments in support of the Stockpile Stewardship program.

LLNS BOG Chairman Norman Pattiz thanks George Miller for his outstanding service to the nation and the Laboratory at ceremonies held to honor the former director in December 2011.



Facts and Figures

LLNL FY2011 Actual Costs: \$1.6 billion



FY2011 Accomplishments “By the Numbers”

Announced the selection of the 11th LLNL director, Dr. Penrose (Parney) C. Albright.

Completed Cycle 16 of the Annual Stockpile Assessment.

Began the W78 Life Extension Program.

Conducted two integrated weapons experiments, one plutonium shock experiment, and five explosively driven pulsed-power experiments.

Fired 286 shots at NIF, including 62 for the ignition campaign and 50 for high-energy-density science.

Achieved a new high in NIF neutron yield of 5.7×10^{14} .

Recovered 90 high-curie radioisotope thermoelectric generators from unsecured locations in the Russian Far East.

Assisted eight African nations with security upgrades to their nuclear facilities.

Co-led the development of the first national strategic five-year plan for nuclear forensics and attribution.

Demonstrated 30-cycle (billion-fold) amplification of DNA in less than three minutes with a new ultrafast PCR device.

Logged more than 5,000 person-hours at NARAC in response to the Fukushima nuclear reactor disaster, including 22 days of 24/7 operations during the height of the crisis.

Based on carbon-14 analyses at CAMS, determined that fat turnover in obese people is 25 percent slower than in normal-weight people.

Determined, via isotopic analysis, the age of the moon and Earth to be 4.36 billion years, instead of 4.5 billion years as previously thought.

Received 890 hours of viewing time on the Gemini Planet Imager and 766 hours on the NASA Spitzer Space Telescope.

Installed the 10-teraflop/s Green Linux Compute Cluster to provide primary computing and data storage resources for the LHC ALICE experiment.

Received two R&D 100 Awards from *R&D Magazine* and five awards for Excellence in Technology Transfer from the Federal Laboratory Consortium.

Received 60 U.S. patents, filed 123 patent applications, and submitted 164 records of invention.

Signed six new Cooperative Research and Development Agreements and 24 new commercial licenses.

Earned \$8.4 million in licensing and royalty income, representing nearly \$350 million in sales of products based on Laboratory technologies.

Received OHSAS 18001 accreditation for the LLNL Occupational Health and Safety Management System.

Reached 90 percent deinventory of special nuclear material requiring the highest level of protection.

Reduced greenhouse gas emissions by more than 15 percent over the last three years, saving 40,000 equivalent metric tons of carbon dioxide.

Decreased energy consumption by 55 million kilowatt-hours or 12.8 percent compared to 2003 usage.

Earned second place (out of 33 teams) in the Connecticut SWAT Challenge and fourth place (out of 29 teams) in the annual Urban Shield exercise.

Hosted the first-of-its-kind cyber combat exercise for 26 teams of cyber security responders from NNSA sites.

Opened the 12,000-square-foot HPC Innovation Center, the first new facility at the Livermore Valley Open Campus.

Conducted 17 functional management reviews involving experts from the LLNS partner organizations and 11 directorate reviews of Laboratory programs and disciplines.

Completed 17 business process improvement projects, including five through the Lean Six Sigma program.

Saw eight LLNL scientists elected as fellows of professional societies.

Hosted 204 postdoctoral fellows (nearly a 100-percent increase over FY2009) as well as 685 students and faculty for research opportunities at the Laboratory.

Showcased the Laboratory to more than 10,000 visitors at LLNL's booth at the inaugural USA Science and Engineering Festival, held on the National Mall in Washington, DC.

Presented nine Science on Saturday lectures in Livermore and Tracy to a total of 4,600 students and parents.

Sponsored the 15th annual Tri-Valley Science and Engineering Fair, where 413 students from 22 schools presented 262 projects.

Hosted 1,300 visitors to the Discovery Center as well as 1,680 community tour participants, 1,860 Fun with Science participants, and 7,500 Super Science Field Trip participants.

Logged nearly 2 million hits per month on LLNL Web pages.

Raised more than \$3.4 million for area nonprofits through the annual Helping Others More Effectively (HOME) campaign.

LLNS President and LLNL Director George Miller presents a check to the Alameda County Library Foundation, one of the agencies that shared \$100,000 in community giving from LLNS. The foundation provides early literacy computer stations to support school readiness and motivate children to read.



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The Board of Governors held one of their quarterly
meetings at the Laboratory in December 2010.



 **Lawrence Livermore
National Laboratory**

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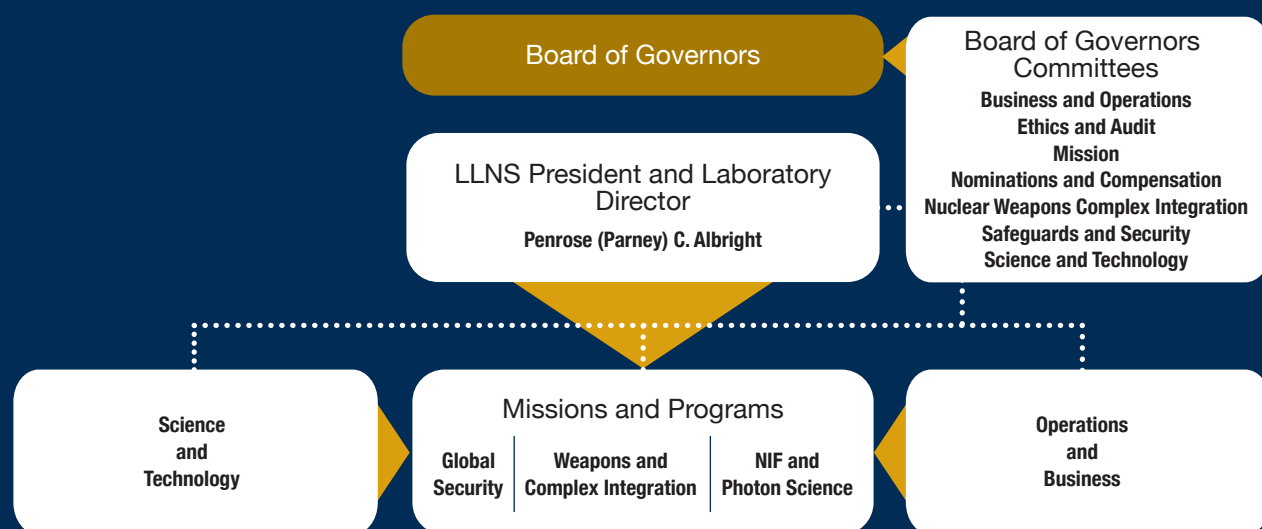


A Partnership of



Battelle
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Lawrence Livermore National Security Organization



The LLNS Board of Governors and its committees provide oversight of the Laboratory in critical areas related to mission and mission-support activities. The LLNS committee charters were approved and the committee members designated during transition in 2007. LANS and LLNS now operate with all of their BOG committees integrated and with joint membership. These committees provide effective oversight in their specific areas through briefings on important Laboratory activities, observations of Laboratory facilities and operations, participation in external review committees and functional management reviews (FMRs), and visits to the Laboratory by committee members between meetings.

Based upon information gathered through these processes, the committees provide guidance, make recommendations,

and identify parent company resources to assist the Laboratory. In FY2011, LLNS held eight FMRs on topics ranging from the Contractor Assurance System to the Laboratory's ethics program. Nine directorate review committee meetings were also held. A total of 80 reviews have been conducted since transition resulting in more than 300 recommendations.

LLNL continues its excellent record in responding to external review committee recommendations. More than 80 percent of the recommendations from FY2010 have been acted on, as have nearly all of the recommendations from prior years. In some cases, these reviews resulted in LLNL importing new commercial best practices; in others, they validated the effectiveness and successful application of new Laboratory processes and procedures.

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U.S. Government Printing Office: 2010/770-187-52026
UCRL-AR-211126-11



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U.S. Department of Energy's National Nuclear Security Administration